

### 3.4 SIGNATURE FLUCTUATIONS

Two phenomena associated with the signature are those of glint and amplitude scintillation. The former causes an apparent angular displacement of the target centroid, and the latter causes returns signal fading. Both are caused by the fact that targets are composed of multiple reflectors and the constructive and destructive interference that occurs among them.

As target position changes, the magnitudes and relative phasing from the reflections change, and the wavefront returned to the radar is distorted. Because tracker processing measures the direction to the target as perpendicular to the received wavefront, distortion leads to tracking errors. A realistic distortion can cause the apparent angle of the target to lie outside of its physical extent.

Glint can be modeled as a correlated noise process. Correlation is usually based on the rotation rate of the target relative to the tracking radar. As the rotation rate increases, the correlation decreases. This trend is intuitively correct, because a high rotation rate would mean that the radar was impacted by a new set of reflectors in a short amount of time and fluctuations would approach a maximum limit.

Amplitude scintillation is comprised of direct and indirect components. The direct component affects conical scan systems because fading can occur when the antenna is pointed at the target, resulting in angular track errors. Monopulse systems can be affected by the indirect component. If a slow AGC is employed, the lag in regulating output of the IF amplifier induce errors in the signal normalization process.

The purpose of the glint subroutine in ESAMS is to calculate the corruption effects of correlated noise on the radars' estimate of target angular position. Due to the fact that glint modulation is correlated to target rotation, it will have a low-frequency component which will be within the pass-band of the radar angle servo. This energy will be reflected in terms of antenna jitter.

Glint error in ESAMS is modeled as a time-correlated Gaussian noise process:

$$g_t = g_{t-1} + \quad [3.4-1]$$

where  $g_t$  and  $g_{t-1}$  are the glint errors at time  $t$  and  $t-1$ . The quantity is a normally distributed random variable with a mean of zero and standard deviation given by:

$$= \frac{1}{4} \cdot \frac{L}{R} \quad [3.4-2]$$

where

$$\begin{array}{ll} L & = \text{effective target length in each channel} \\ R & = \text{total range to target} \end{array}$$

The correlation is developed by capturing the dependency on the rotation rate of the target for each channel, and the glint half power frequency is attained from the following relation (elevation channel example):

$$g_p = \left| \frac{4 \cdot \dot{L}_p}{\lambda} \right| \quad [3.4-3]$$

where

$$\begin{aligned} g_p &= \text{glint half power frequency in elevation} \\ \lambda &= \text{radar wavelength} \\ \dot{\phantom{x}} &= \text{rate of change of elevation angle} \\ L_p &= \text{effective target length in elevation} \end{aligned}$$

The resulting correlation coefficient is

$$= \exp(-g_p \cdot DTN) \quad [3.4-4]$$

where DTN is the time between samples.

Finally, the standard deviation of the correlated glint becomes:

$$\sigma_o = \sqrt{(1 - \rho^2)} \quad [3.4-5]$$

If the target angular rate goes to zero, then  $\rho$  also goes to zero. This outcome says that the reflection points remain the same, and there will be no wavefront distortion. Thus, the glint corruption will be zero.

**Scintillation.** As mentioned previously, scintillation causes a fading and reinforcement of the signal that is reflected off of the target aircraft. For monopulse radars, the only impact will be caused by the inability of the AGC to hold the output of the IF amplifier at the desired level. As illustrated in figure 3.4-1 this can cause a difference between  $E_0$  and  $\bar{E}_0$ , with a resulting error in normalization. In addition to the angle loop, an AGC can be present in the range and Doppler loops.

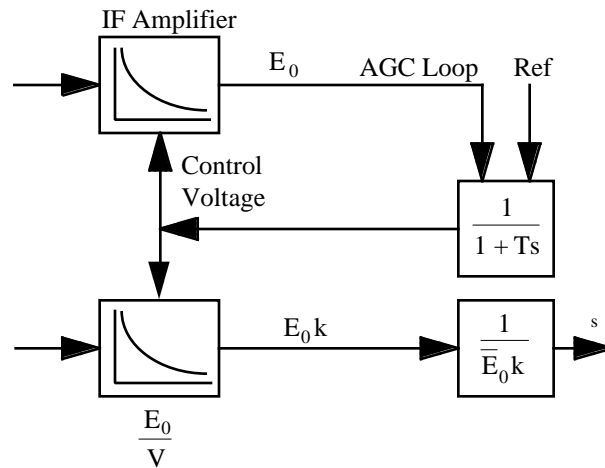


FIGURE 3.4-1. Angle Extraction with a Monopulse.

The nature of the scintillation process will be dependent on the target aircraft structure as viewed by the missile radar. For example, the reflection statistics are different for a structure composed of one dominant reflector when compared to one consisting of a number of approximately equal reflectors.

ESAMS models scintillation effects using one of two user-selectable distributions: exponential or chi-squared with four degrees of freedom (DOFs). The exponential distribution has the form:

$$p(x) = \exp(-x/\mu)/\mu \quad (x \geq 0) \quad [3.4-6]$$

where  $\mu$  is the mean

The chi-squared distribution with four DOFs can be computed from the sum of two chi-squared deviates (each having two DOFs). The expression for chi-squared distribution with two DOFs is identical to the exponential distribution in Equation 3.4-6.

As with glint, the scintillation is modeled as a time-correlated process with the correlation coefficient given by:

$$CORCOF = e^{-(CURTIM-OLDTIM)/CORTIM} \quad [3.4-7]$$

where

CURTIM= current time  
 OLDTIM= time of last calculation  
 CORTIM= correlation time

The new correlated RCS value is given by

$$CURVAL = CORCOF \cdot OLDVAL + (1 - CORCOF) \cdot CURVAL$$

where

OLDVAL = previous correlated RCS value.

TABLE 3.4-1. Data Requirements.

Data Item		Accuracy	Sample Rate	Comments
1.2.2.1	Transmit signal	$\pm 1$ kW	Pulse-to-pulse	Limit to 10 s intervals.
1.2.2.2	Received signal	$\pm 0.5$ dB	Pulse-to-pulse	Limit to 10 s intervals.

### 3.4.1 Objectives and Procedures

Separate ESAMS runs were performed using no scintillation, exponential scintillation, and chi-square scintillation in order to examine their relative impacts on angular tracking errors. The target signatures used in the sensitivity analyses were spherically symmetric and were chosen to have the values of  $1 \text{ m}^2$  and  $0.001 \text{ m}^2$  in order to simultaneously examine the effects of scintillation with different target signatures.

### 3.4.2 Results

Figure 3.4-2 compares the effect of adding scintillation to a 1 square meter fuzzball signature using the two default distributions in version 2.6.2 (chi-squared and exponential). Differences in angle tracking errors,  $\sigma^2 = az^2 + el^2$ , are plotted for a short-range tracking system. The scintillation effects are sufficiently small in both cases that they have negligible effect on system effectiveness.

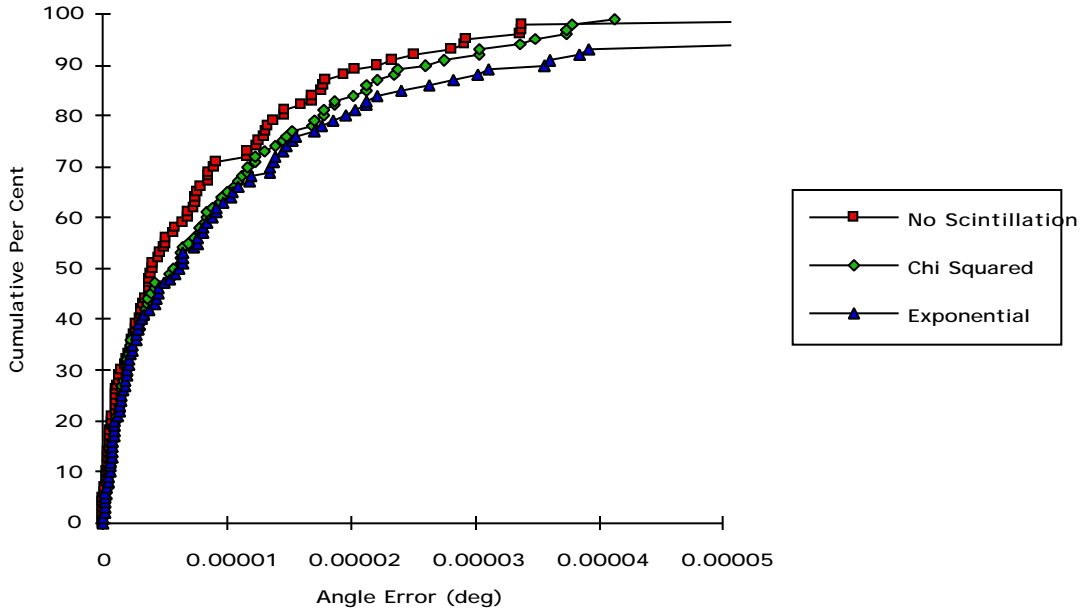


FIGURE 3.4-2. Scintillation Errors (0 dBsm Signature).

When scintillation is added to a target with smaller cross-sections (as shown in figure 3.4-3) the relative dispersion in angle tracking errors is more significant; however, missile guidance will not be significantly affected.

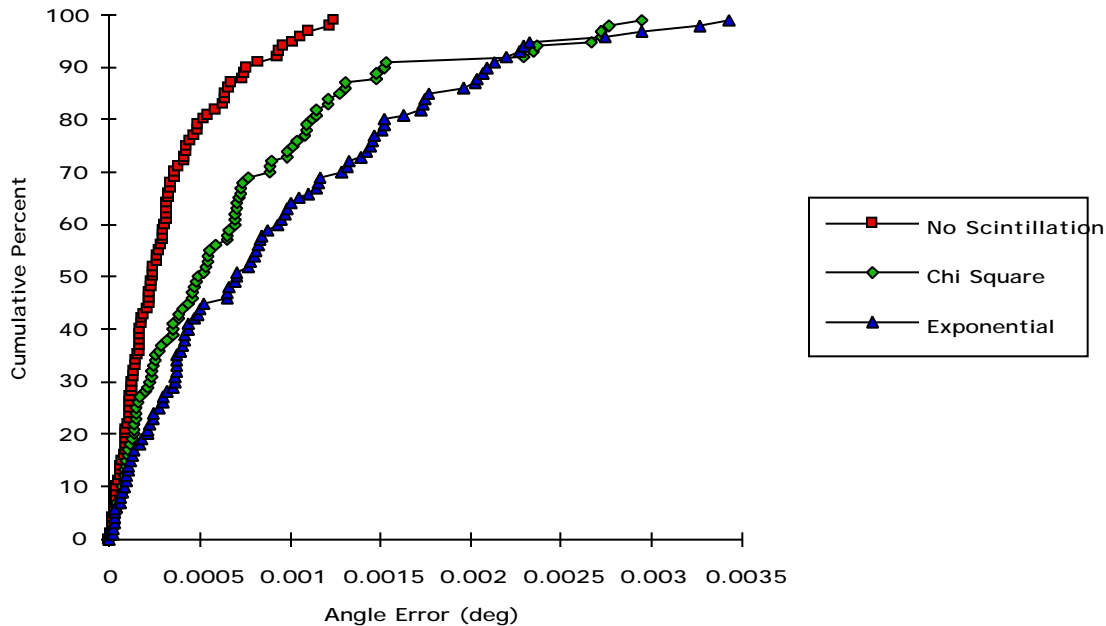


FIGURE 3.4-3. Scintillation Errors (-30 dBsm Signature).

### 3.4.3 Conclusions

Both exponential scintillation and chi-square scintillation have a negligible effect on tracking errors for targets with conventional signatures ( $> 1 \text{ m}^2$ ). This is a consequence of the assumption that for non-TWS (track-while-scan) radars, the AGC is implicitly modeled as instantaneous. Therefore the receiver sensitivity (volts per degree track error) is independent of signal levels over the detection threshold.

For lower target signatures (as the  $0.001 \text{ m}^2$  examined here), there is a larger relative effect of scintillation. For these signatures, the target signal is closer to the detection threshold and a random drop in signature (due to scintillation) is more likely to cause a break-lock and larger overall track errors as demonstrated in Figure 3.4-3. Although larger than the errors for a  $1 \text{ m}^2$  target, the angle errors for the  $0.001 \text{ m}^2$  target are still sufficiently small that they do not have any significant impact on the predicted missile guidance and intercept capabilities.

